# Real-Time Iris recognition Biometric Attendance System Using Image Processing Techniques

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**Abstract -** Accurate and secure attendance monitoring is a critical requirement in educational and corporate environments. Traditional attendance systems such as manual registers, RFID cards, and fingerprint sensors suffer from limitations including proxy attendance, data tampering, time consumption, and hygiene concerns. This research presents a contactless real-time biometric attendance system based on iris recognition, leveraging image processing and feature extraction methods to achieve high accuracy and robustness. The proposed system captures eye images in real-time using a standard camera, performs iris segmentation, extracts unique features, and matches them with stored templates to automatically record attendance. Experimental evaluation demonstrates the system's potential for real-time deployment with low False Acceptance Rate (FAR) and False Rejection Rate (FRR). The solution is cost-effective, scalable, and highly suitable for post-pandemic environments where contactless authentication is essential.

Keywords— Iris recognition, biometric authentication, attendance system, image processing, feature extraction, template matching.

## 1. INTRODUCTION

Real-Time Iris recognition Attendance management plays a vital role in academic institutions and workplaces. Conventional approaches such as manual roll-calls or card-based systems are vulnerable to manipulation, proxy attendance, and human error. With advancements in digital identity verification, biometric authentication has emerged as a secure alternative. Biometrics utilize unique physiological or behavioral traits such as fingerprints, facial features, voice patterns, and iris texture for identity verification.

Among all biometric modalities, iris recognition stands out due to its extremely rich and stable texture patterns that remain unchanged throughout a person's life. The iris is unique even among identical twins, making it one of the most reliable identifiers. Additionally, iris-based authentication is completely contactless, addressing hygiene concerns highlighted during global pandemics.

C. Objectives and Contributions

1. To develop a contactless, real-time iris-based

This research aims to design and implement a robust iris-based attendance system capable of real-time operation using affordable hardware and open-source technologies.

A. Background and Motivation

Real-Time Biometric authentication has gained significant attention as a secure and reliable solution for identity verification, especially in applications where accuracy and tamper-resistance are essential. Traditional attendance systems—including manual registers, RFID cards, and fingerprint sensors—are increasingly ineffective due to issues such as proxy attendance, data manipulation, human error, and hygiene concerns. The need for contactless and highly accurate systems became even more urgent during the COVID-19 pandemic, which exposed the risks associated with touch-based authentication methods. Among all biometric modalities, iris recognition stands out due to its complex and unique texture patterns that remain stable throughout an individual's lifetime, offering superior accuracy, forgery resistance, and robustness to environmental variations. With advancements in computer vision and affordable imaging technology, implementing real-time iris recognition using standard cameras has become feasible. This motivates the development of a low-cost, scalable, and contactless iris-based attendance system that enhances security, eliminates proxy attendance, reduces administrative overhead, and meets modern organizational requirements for hygiene and automation..

B. Problem Statement

1. Traditional attendance systems such as manual registers, RFID cards, and fingerprint scanners are prone to proxy attendance, data manipulation, and human error, making them unreliable for secure identity verification.
2. Existing biometric methods that require physical contact pose hygiene risks, especially in post-pandemic environments, and are inefficient for large-scale, real-time authentication.
3. There is a lack of affordable, contactless, and highly accurate biometric attendance solutions that can operate efficiently using standard camera hardware and lightweight image processing techniques.

attendance system that ensures accurate and secure identity verification.

2. To design a robust iris segmentation and feature extraction pipeline that minimizes errors and performs reliably under varying lighting and environmental conditions.

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3. To implement an efficient template matching and automated attendance logging mechanism using affordable, readily available camera hardware.
4. To contribute a low-cost, scalable, and high-accuracy biometric solution that eliminates proxy attendance, enhances hygiene, and outperforms traditional attendance methods.

## 2. LITERATURE REVIEW

Real-Time Biometric identification has steadily evolved over the past two decades as organizations seek more secure and reliable methods of verifying individuals. Early research in biometrics explored fingerprints and facial recognition due to their accessibility, but both modalities showed limitations: fingerprints are affected by skin conditions and require physical contact, while face recognition suffers from variations caused by lighting, pose, occlusions, and aging. As a result, researchers began examining the iris, a region of the eye characterized by intricate, naturally occurring patterns that remain stable over a person's lifetime. The uniqueness and permanence of the iris made it a strong candidate for high-security authentication systems.

Initial academic work in iris recognition primarily focused on segmentation—accurately isolating the iris despite surrounding structures such as eyelids, eyelashes, and reflections. Researchers proposed various edge detection and circular approximation techniques to improve boundary localization. Later studies expanded toward robust feature extraction methods capable of capturing the subtle textural details within the iris. Techniques based on frequency analysis, statistical pattern encoding, and phase-based representations were evaluated extensively to determine their suitability for large-scale identification.

In parallel, advancements in machine learning and image processing opened the possibility of performing iris recognition under less controlled environments. Studies began addressing challenges such as off-angle gaze, inconsistent illumination, motion blur, and low-resolution captures from consumer-grade cameras. Although high-performance systems emerged, many required specialized sensors or infrared illumination, limiting deployment in cost-sensitive domains like educational institutions.

More recent work has shifted toward optimizing computational efficiency, enabling real-time processing on lightweight hardware while preserving accuracy. Researchers have also examined hybrid approaches that combine classical image processing with learning-based refinement for improved reliability. Despite these advancements, there remains a noticeable gap in research focused on developing affordable, easy-to-deploy iris recognition systems specifically tailored for attendance management. This motivates the need for practical solutions that balance accuracy, speed, cost, and usability.

## 3. THEORITICAL FRAMEWORK

The theoretical framework for an real-time iris-based biometric attendance system is established on the principles of digital image processing, statistical pattern recognition, and biometric decision theory. Central to the system is the premise that the iris contains a highly distinctive and stable texture pattern that can be mathematically encoded and compared across individuals. The following subsections describe the theoretical foundations that govern acquisition, segmentation, feature extraction, and matching.

1. Iris Uniqueness and Pattern Stability

The real-Time iris texture is a complex two-dimensional pattern composed of furrows, freckles, crypts, and radial ligaments. Mathematically, the iris texture $I(x, y)$can be modeled as a non-stationary signal with spatial variations in frequency and phase. Because these patterns are formed randomly during embryogenesis, the probability of two irises being identical is extremely low:

$$P(I_a = I_b) \approx 0$$

where $I_a$and $I_b$represent independent iris patterns.

2. Image Acquisition Model

A captured iris image can be represented as:

$$I_c(x, y) = I_t(x, y) * h(x, y) + n(x, y)$$

where

- $I_t(x, y)$= true iris texture,
- $h(x, y)$= imaging system's point spread function,
- $n(x, y)$ = noise (illumination variation, shadows, reflections).

Enhancement methods such as histogram equalization ensure that iris texture contrast is preserved for segmentation.

3. Iris Segmentation Theory

The inner (pupil) and outer (limbus) iris boundaries are theoretically modeled as circles:

$$(x - x_0)^2 + (y - y_0)^2 = r^2$$

where $(x_0, y_0)$ is the center and $r$ is the radius. To detect these boundaries, the Circular Hough Transform maximizes:

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$$H(r, x_0, y_0) = \sum_{x,y} \delta((x - x_0)^2 + (y - y_0)^2 - r^2)$$

Identifying the optimal $(x_0, y_0, r)$enables accurate isolation of the iris region.

4. Normalization (Rubber Sheet Model)

The iris surface is normalized to a fixed dimension to account for pupil dilation. The transformation is defined as:

$$I_N(\theta, r) = I(x(\theta, r), y(\theta, r))$$

where

$$x(\theta, r) = (1 - r)x_p(\theta) + rx_l(\theta)$$
$$y(\theta, r) = (1 - r)y_p(\theta) + ry_l(\theta)$$

Here, $(x_p, y_p)$ and $(x_l, y_l)$ denote pupil and limbus boundary points respectively.

5. Feature Extraction Theory

The normalized iris texture is convolved with 2D Gabor filters to extract discriminative features:

$$G(x, y) = \exp(-\frac{x'^2 + y'^2}{2\sigma^2})\exp(j2\pi f x')$$

These generate binary feature codes representing the local phase of iris texture signals:

$$C = \text{sign}(\Re(G * I_N))$$

This binary encoding increases robustness to illumination and contrast variations.

6. Template Matching and Decision Theory

Similarity between two iris codes $C_1$and $C_2$is computed with the Hamming Distance:

$$HD = \frac{1}{N}\sum_{i=1}^{N} (C_{1i} \oplus C_{2i})$$

A match is accepted when:

$$HD \leq T$$

where $T$is the decision threshold tuned to minimize the False Acceptance Rate (FAR) and False Rejection Rate (FRR).

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## 4. SYSTEM IMPLEMENTATION

The implementation of the real-time iris recognition biometric attendance system involves an end-to-end pipeline that integrates image acquisition, preprocessing, segmentation, normalization, feature extraction, template generation, matching, and attendance logging. Each component is designed to function efficiently on standard computing hardware while maintaining high recognition accuracy. The system is implemented using Python, leveraging OpenCV for image processing and NumPy for mathematical operations. The following subsections provide a detailed explanation of the implementation phases.

1. Image Acquisition Module

The system begins by capturing a live image of the user's eye through a standard USB webcam or a laptop camera. The camera operates at a minimum resolution of 640×480 pixels to ensure sufficient detail in the iris region. Real-time video frames are displayed on-screen, guiding the user to position their eye within a predefined bounding box. Once alignment is detected—typically through a Haar-cascade or DNN-based eye detector—a high-quality frame is captured. This ensures that only clear and focused images proceed to the later stages, significantly improving the reliability of segmentation and feature extraction.

2. Image Preprocessing

To enhance the captured image for segmentation, the system applies several preprocessing steps. The image is first converted to grayscale, reducing computational load and emphasizing texture details. Noise in the image—arising from lighting variations or camera imperfections—is minimized using Gaussian blurring and median filtering. Contrast enhancement is achieved through histogram equalization, which improves the visibility of iris features in poorly lit environments. Additionally, reflections or glare around the cornea are reduced using adaptive thresholding techniques. This preprocessing ensures that edge detection algorithms can reliably identify iris boundaries.

3. Iris Segmentation

Segmentation represents the most important stage of the system, as accurate boundary localization significantly influences overall performance. The pupil and limbus boundaries are approximated as circles; therefore, the Circular Hough Transform is used to detect both inner and outer iris contours. The algorithm scans multiple radius ranges to identify the circular edges with the highest accumulator votes. Eyelids and eyelashes—common sources of segmentation noise—are detected using linear edge filters and masked out before further processing. The segmentation output is a binary mask that isolates the iris region while removing noise elements such as eyelid shadows, eyelashes, and reflections. This step ensures that only relevant iris texture is fed into the normalization stage.

4. Normalization Using Rubber Sheet Model

Variations in pupil dilation and head movement lead to differences in iris appearance across different captures. To address this, the segmented iris is transformed to a fixed-size rectangular block using the Rubber Sheet Model. The circular iris region is remapped into polar coordinates, producing a normalized image with consistent dimensions (typically 64×512). This unwrapping process ensures that iris features remain comparable across different images. During

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normalization, occluded regions are flagged using a mask that excludes unreliable texture information from later stages.

5. Feature Extraction and Template Generation

The system extracts discriminative features from the normalized iris using 2D Gabor filters. These filters capture local frequency and orientation variations, which are essential in distinguishing between different irises. Each filtered output is converted into a binary iris code by sampling the phase information. The result is a compact binary string representing the unique pattern of the user's iris. In parallel, a noise mask is generated to mark unstable regions affected by eyelashes, reflections, or segmentation errors. Both the iris code and mask are stored as the user's template within a secure database.

6. Template Matching

During authentication, the extracted iris code is compared with stored templates using the Hamming Distance metric. The algorithm compares only the bits not masked by noise, ensuring accurate similarity measurement. Multiple rotations (±15 degrees) are tested to compensate for slight head tilts during image capture. A match is declared when the minimum Hamming Distance falls below the system-defined threshold. This decision threshold is tuned experimentally to minimize both False Acceptance Rate (FAR) and False Rejection Rate (FRR).

7. Attendance Logging and Database Integration

Once a user is authenticated successfully, the system automatically logs their identity along with the timestamp into a database. The attendance database is implemented using SQLite for lightweight deployments or MySQL for larger institutional setups. Each record stores the user ID, login time, and date. The user interface allows administrators to view daily and monthly attendance summaries, export reports, and register new users securely by capturing their iris templates during enrollment.

8. User Interface and System Integration

A graphical user interface (GUI) is implemented using Tkinter or PyQt, offering an intuitive layout for both users and administrators. Users only need to look at the camera for attendance, while administrators can manage enrollments, check logs, and generate reports. The system is modular, enabling each component—image capture, preprocessing, matching, and reporting—to function independently or as part of the full pipeline.

This implementation framework ensures that the real-time iris-based attendance system operates efficiently, achieves high accuracy, and remains practical for deployment in real-world educational and organizational environments.

**The Decision Matrix (Expert System)**

The Decision Matrix, functioning as the expert system component of the real-time iris-based attendance model, plays a crucial role in determining whether the captured biometric information corresponds to a valid user in the database. Unlike simple threshold-based decisions, the expert system applies a structured evaluation process where multiple parameters are assessed before confirming a match. This ensures greater reliability, reduces false outcomes, and strengthens the overall decision-making accuracy of the system.

The matrix evaluates several critical factors: segmentation quality, feature extraction consistency, noise level, Hamming distance score, and rotation compensation results. Each parameter is assigned a weight based on its importance to the recognition process. For instance, segmentation quality receives a high weight because inaccurate boundary detection can undermine all subsequent stages. Similarly, the Hamming distance score, which measures similarity between templates, is assigned significant influence in the final decision.

A simplified decision matrix can be illustrated as follows:

| **Criteria** | **Weight** | **Score Range** | **Decision Influence** |
|---|---|---|---|
| Segmentation Accuracy | High | 0–10 | Strong |
| Noise Mask Percentage | Medium | 0–10 | Moderate |
| Feature Extraction Stability | High | 0–10 | Strong |
| Hamming Distance Value | Very High | 0–10 | Critical |
| Rotation Matching Consistency | Medium | 0–10 | Moderate |

The system computes a weighted score:

$$D = \sum_{i=1}^{n} (W_i \times S_i)$$

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where
$W_i$ = weight of criterion i,
$S_i$ = score of criterion i,
$n$= number of evaluation criteria.

A final decision rule is applied:

$$\text{If } D \geq T, \text{ then Match; else No Match}$$

where $T$is the decision threshold determined through testing.

By incorporating multiple parameters instead of relying solely on Hamming distance, the Decision Matrix reduces uncertainty and mimics expert human judgment. This produces more accurate and stable recognition results even under noisy or imperfect imaging conditions, making the system more robust and deployment-ready for real-world attendance environments.

## 5. EXPERIMENTAL RESULTS

The experimental evaluation of the real-time iris recognition biometric attendance system was conducted to assess its accuracy, processing speed, robustness under varying environmental conditions, and overall usability in real-time scenarios. A dataset of 40 individuals was created, with each participant providing 10 iris samples captured using a standard 720p webcam. The images were collected under different lighting conditions—natural light, indoor fluorescent light, and low-light settings—to test the system's adaptability. The experiments focused on segmentation performance, matching accuracy, false acceptance/rejection rates, and average runtime per recognition cycle.

The segmentation module achieved an accuracy of **93.8%**, correctly identifying the iris boundaries in most samples. Failures were primarily caused by excessive glare, partially closed eyelids, or improper positioning of the eye relative to the camera. When segmentation failed, those samples were excluded from feature extraction to maintain system reliability. The normalization and feature extraction processes were found to be efficient, producing stable iris codes with minimal noise interference.

The matching accuracy of the system was evaluated using genuine and imposter comparisons. Genuine comparisons (same user, different samples) achieved an accuracy of **97.2%**, indicating strong consistency in the generated iris templates. In contrast, imposter comparisons (different users) produced a False Acceptance Rate (FAR) of **1.4%** and a False Rejection Rate (FRR) of **2.1%**. These values demonstrate that the system maintains a good balance between security and usability, performing reliably even without specialized infrared hardware.

Runtime analysis showed that the average time required for a complete recognition cycle—including capture, preprocessing, segmentation, feature extraction, and matching—was **1.8 seconds**, making the system suitable for real-time attendance environments. The attendance logging module also performed efficiently, updating the database almost instantly after successful authentication.

Additional stress tests were conducted by introducing slight rotations and variations in eye distance from the camera. The system maintained recognition stability within a rotation range of ±15 degrees and distance variations of 10–15 centimeters. Beyond these ranges, segmentation errors increased, indicating the need for user alignment assistance in uncontrolled environments.

Overall, the experimental results confirm that the implemented iris recognition attendance system delivers high accuracy, fast processing, and strong reliability using only standard camera hardware. These outcomes highlight the system's practicality and feasibility for deployment in educational institutions and offices without requiring costly biometric equipment.

## 6. DISCUSSION

The experimental findings demonstrate that the proposed iris recognition biometric attendance system is both technically feasible and practically effective for real-world deployment. The performance metrics indicate strong recognition accuracy, rapid processing times, and relatively low error rates, confirming that high-quality iris authentication does not necessarily require specialized infrared cameras or costly sensors. Instead, the use of a conventional webcam combined with robust image processing techniques provides a viable solution for environments such as classrooms, offices, and secure facilities.

One of the notable outcomes is the high segmentation accuracy, which significantly influences the reliability of feature extraction and matching. Most segmentation errors occurred under conditions involving strong reflections, partially closed eyelids, or sudden user movement. This highlights the importance of stable user positioning and adequate lighting. Nonetheless, the system's ability to maintain accuracy across diverse lighting conditions suggests strong adaptability in non-controlled settings. Future improvements such as real-time glare detection or guided alignment prompts could further reduce segmentation-related errors.

The matching results show a favorable balance between False Acceptance Rate (FAR) and False Rejection Rate (FRR), indicating that the threshold used for decision-making is appropriately tuned. Although the system achieved impressive accuracy, the slight presence of false rejections suggests that some users' iris features may be affected by noise, motion blur, or inconsistent capture angles. Incorporating advanced feature encoders or lightweight deep-learning-based refinement modules could enhance template stability and further reduce FRR.

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Processing speed is another significant factor in evaluating the practicality of the system. The average recognition time of under two seconds ensures smooth operation, even in scenarios involving multiple users in quick succession. This speed is largely due to efficient preprocessing methods and an optimized matching algorithm, reaffirming the suitability of the system for real-time attendance monitoring.

The system's robustness against rotations and minor distance variations highlights its tolerance toward natural user movements. However, performance degradation beyond certain angles emphasizes the need for user alignment assistance in fully uncontrolled environments. Integrating eye-tracking cues or an automatic capture trigger based on optimal positioning could improve consistency.

Overall, the discussion demonstrates that the system successfully meets its design objectives: accuracy, speed, affordability, and contactless operation. While there is room for refinement, the results confirm that a pure camera-based iris recognition system can serve as an effective and scalable alternative to traditional attendance mechanisms in modern institutional settings.

## 7. CONCLUSION AND FUTURE SCOPE

The proposed real-time iris recognition biometric attendance system successfully demonstrates that reliable, contactless, and automated identity verification can be achieved using standard camera hardware and efficient image processing algorithms. The system delivers high recognition accuracy, low error rates, and quick processing times, making it suitable for real-time attendance applications in educational institutions and workplaces. Its contactless operation enhances hygiene, while its resistance to proxy attendance and data manipulation strengthens overall security compared to traditional biometric and manual systems. Despite these strengths, there are areas for further enhancement. The system's performance can be improved under extreme lighting conditions or when the user's eye is not properly aligned with the camera. Future work could involve integrating deep learning-based segmentation models, liveness detection mechanisms to prevent spoofing attempts, and adaptive illumination correction to increase robustness. Additionally, the system may be expanded to support multimodal biometrics by combining iris features with face or voice recognition for higher security in sensitive environments. Cloud-based attendance analytics, mobile deployment, and integration with institutional management software also present promising extensions. Overall, this project establishes a strong foundation for scalable, secure, and cost-effective biometric attendance systems and offers multiple avenues for advancement in the next generation of smart authentication technologies.

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